MINING ACTIVITIES IN CONTEMPORARY AND ANCIENT GREECE

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The Greek National Committee organized in Greece, on September 1992, the 71st Meeting of the World Mining Congress.

Professor John Economopoulos addressed the audience with a speech on the mining in modern as well as in ancient Greece.

This speech impressed the participants who requested its publishment in «MINERAL WEALTH» so that they would be able to peruse and analyze it.

Our magazine has granted this request of the participants of the Meeting and publishes herebelow the text of Prof. J. Economopoulos' speech.

Τον Σεπτέμβριο του 1992, η Ελληνική Εθνική Επιτροπή οργάνωσε στην Ελλάδα την 71η συνάντηση του Διεθνούς Μεταλλευτικού Συνεδρίου (World Mining Congress).

Στην συνάντηση αυτή ο καθηγητής του Ε.Μ. Πολυτεχνείου κ. Ιωάννης Οικονομόπουλος μίλησε για την Μεταλλεία στην σύγχρονη, αλλά και στην αρχαία Ελλάδα.

Η ομιλία αυτή έκανε πολλή εντύπωση στους συνέδρους, οι οποίοι και μας ζήτησαν να την δημοσιεύσουμε στον «ΟΡΥΚΤΟ ΠΛΟΥΤΟ», ώστε να έχουν την δυνατότητα να την μελετήσουν και να την αναλύσουν.

Το περιοδικό μας έκανε δεκτή την παράκληση αυτή των συνέδρων και δίνει σήμερα στην δημοσιότητα όλο το κείμενο της ομιλίας του καθηγ. Ι. Οικονομόπουλου.

ABSTRACT

Greece, in contrast to the relatively small size of the country (132.000 km^2) contains an extraordinary variety of rocks in which exceptional mineral deposits of commercial value exist. The country possesses world class deposits of several industrial minerals (magnesite, bentonite, perlite, pumice, asbestos, marbles) and metallic ores (bauxite). Significant deposits of Ni, Pb-Zn-Cu-Fe, Cr and Mn also very extensive since Greece holds the 8th place in the world on lignite-brown coal production.

The Greek mining industry played a very important role in the industrial development of the country, especially after the second world war, but nevertheless faces to day many problems due to various reasons, like the abundance of several minerals produced in some countries (S. Africa, Australia) the developments in the Eastern European countries and the competition from the so called "third world countries" which besides some unquestionable advantages (low salaries and wages, huge deposits, lack of legislation for the protection of the environment etc) are also helped by the EEC through the well known Lome conventions. Anyway, mining and metallurgical activity in Greece is nothing new. It started probably around 1500 B.C. Later, with the beginning of the 8th century B.C. several mining centers appear and develop and some of them (Lavrion, Macedonian mines) became famous. There is no doubt that among the famous mining and metallurgical centers of the Greek antiquity Lavrion remains at the top. Amazing methods and techniques were developed there in order to extract, process and smelt the ore to produce 3500 tons of Silver and 1.400.000 tons of Lead between the 7th and 1st centuries B.C.

Mining and metallurgical operations in ancient Greece played an important role in the creation of the ancient Greek civilization, the golden age of Pericles, the temples and mosaics in Macedonia and the erection of glorious monuments like the Athenian Acropolis and many others.

The tectonic structure of Greece is rather complex, characterized by six main geotectonic zones which contain a wide variety of igneoris, sedimentary and metamorphic rocks.

As a result of the various metallogenetic actions that occured during the geological ages (from Paleozoic Silurian - Devonian to Quarternary Alluvium) a considerable number of important deposits of coal, ores and industrial minerals were formed.

Therefore, we can say that in contrast to the relatively small size of the country (approx. area 132.000 Km$^{2)}$ Greece contains an extraordinary variety of rocks in which some exceptional mineral deposits of commercial value exist.

The country possesses world class deposits of several industrial minerals, notably magnesite, bentonite, perlite, pumice and marbles. The only world class deposits in the metallic ores field are the bauxite deposits of Central Greece, whereas significant deposits of Ni, Pb-Zn-Cu-Fe (mixed sulphides), Cr and Mn exist and are under exploitation. Quartz, feldspars, kaolin, emery and other minerals are also mined in a secondary scale.

On the other hand, due to the unlimited deposits of limestone, clays, schists and slates, cement industry is flourishing and at the same time very big quantities of construction raw materials (sand, gravel and dimension stones) are also produced.

Finally, coal (lignite) mining is very extensive, since Greece holds the 8th place in the world on lignite-brown coal production.

For simplicity, the rocks of Greece may be divided

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into the following types, each containing a number of characteristic minerals:

— Sedimentary rock formations, such as limestone, shale and chert, which hold bauxite, pyrolusite, iron-nickel laterite deposits, gypsum etc.

— Metamorphic rock formations, such as marble, crystalline schists and gneiss, containing marbles, mixed sulphide ores, emery, magnesite etc.

— Intrusive plutonic and volcanic rocks, which form the host for kaolin, bentonite, perlite, pumice etc.

Relatively recent geological exploration carried out by the various private Enterprises as well as by the Institute of Geology and Mineral Exploration has focused attention on a number of mineral deposits, which may support future mining and processing operations.

The first results of this exploration activity are already bearing fruits, since a rather extensive extraction of pegmatites (quartz, feldspars) started a few years ago (Macedonia, Northern Greece) whereas a wollastonite project is under examination on a pilot plant scale (Thrace, North-Eastern Greece). Exploration for gold was also performed in Northern Greece in order to ascertain the possibility of economic extraction of gold from sulphide ores as well as recovery of gold from placer (alluvial) deposits.

An important project for the exploitation of mixed sulphides deposit in Peloponnese, Southern Greece, is also under examination. The volcanic rocks have also been under scrutiny and reserves of zeolites and native sulphur are being evaluated. Large quantities of zeolitic minerals have been discovered in some Greek islands of the Aegean sea, whereas a major programme to exploit the native Sulphur deposits in the island of Milos is underway.

Finally, in the fuel minerals sector, huge deposits of Lignite and peat have been located recently, mainly in Northern Greece.

It is remarkable to note that Greece:

— Holds 2,75% of world bauxite reserves and is the only EEC bauxite producer, since French production comes almost to an end.

— Is the only Nickel producer on EEC European ground and covers more than 2% of Western world production of Nickel.

— Covers 8,5% of world production of magnesite and is the major of the two EEC producers.

— Is the first European producer of perlite and the second largest producer in the world.

— Is the first European producer of bentonite and the second largest producer in the world.

Besides the above mentioned Greece is the only EEC producer of Fe-Cr, one of the world's largest producers and exporters of pumice and an important producer and exporter of asbestos and marbles, the latter in a great variety and colours.

The production of the main mining and metallurgical products during the years 1989 and 1990 are given in the following Table.

GREEK PRODUCTION OF MAIN MINING AND METALLURGICAL PRODUCTS (m. tons)

PRODUCT	1989	1990
Coal (Lignite)	50,800,000	51,500,000
Oil (barrels)	7,500,000	6,500,000
Bauxite	2,535,000	2,610,000
Ni ore (laterite)	2,043,000	2,100,000
PbS (concentrates)	36,000	37,400
ZnS (concentrates)	47,200	51,500
Cr_2O_3 (concentrates)	78,000	54,200
FeS_2 (concentrates)	30,000	37,200
Dead burned magnesia	215,000	215,000
Mg products	115,000	70,000
Fe-steel	2,050,000	2,150,000
Fe-Ni	16,000	15,700
Fe-Cr	43,500	30,300
Al	150,000	150,000
Bentonite	530,000	500,000
Perlite	217,000	220,000
Pumice stone	640,000	600,000
Asbestos (fibres)	73,300	65,600

Greek mining involves both large and small scale mining, by both underground and opencast methods. Very strict regulations concerning the protection of the environment compel many mining companies to shift towards underground extraction with obvious consequences in cost formation.

The degree of processing varies from one mineral to another. Some important minerals such as perlite and pumice require little more than crushing and grading but where beneficiation is required a number of sophisticated techniques (flotation, differential flotation, gravity separation, heavy media separation, photometric and magnetic separation etc.) are employed in order to yield high grade saleable products.

Some mining companies treat the ore metallurgically or convert the exploited minerals into other products, for instance bauxite to alumina and aluminium metal, nickeliferous laterites and chromite to ferroalloys (Fe- Ni and Fe-Cr respectively), magnesite into dead-burned magnesia, calcined magnesia and refractory bricks, limestone into cement etc.

A range of small, medium and large size companies are involved in the activities of the Greek mining industry. The state plays an important role in mining, either directly through public Enterprises, or major shareholding held by National Banks. Oil, coal and radioactive minerals belong to the State, according to the existing legislation. Overall, the Greek mining industry can be considered as a modern, «hi-tech» industry recognised as an innovator in certain fields. The Greek mining industry played a very important role in the industrial development of the country, especially after the 2nd World War. Certain big and medium size private, as well as state-owned companies, were established -besides the existing ones- in order to exploit the great variety of minerals and the relatively large amounts of coal and mineral resources discovered, thus gradually expanding their activities wherever was business interest. At the same time, a lot of isolated areas -particularly those of northern and mountainous Greece- were industrially developed. As a consequence in the mining sector appeared many chances of employment for workers, technicians and geoscientists. Furthermore, the numbers of graduated mining engineers found to be increasing in order to satisfy the industrial needs. The contribution of the Mining Sector in the general financial situation of Greece is always highly appreciated. During the last 20 years, contrary to what was happening in many EEC countries, the Greek mining and metallurgical activities showed an essentially upward tendency with exports usually developing at a fast rate, thus giving to the Mining Sector one of the most favourable positions among the other significant industrial and commercial sectors of the Greek economy. Nevertheless Greek mining industry faces a lot of problems to day, due to various reasons, like the abundance of several minerals in some countries (Australia, South Africa), the dramatic developments in the Eastern European countries and mainly the competition from the so called «third world countries» which besides some unquestionable advantages (huge deposits exploited by surface mining, extremely low salaries and wages, lack of strict legislation for the protection of the environment etc.) are also helped by the EEC through the well known LOME conventions. In addition to that some countries, offer minerals in the international market by following a dumping procedure which besides being unethical requires the application of antidumping control which is very difficult for the free economy western world.

We must also mention the still pending action of EEC to establish a community mining policy that would help the countries presenting considerable mining activity, like for instance the countries of Southern Europe (i.e. Portugal, Greece, Spain etc.) and also take precautions against the severe consequences of LOME agreements that concern the African, Carribean and Pacific countries. On the other part, the lack of antidumping activities badly affects the Greek mining industry.

In order to overcome this situation, which results not only to the reduction of the production of certain minerals but endangers even the existence of the Greek mining industry, the Greek Government as well as the mining Enterprises must examine several ways to improve the scheme of the Greek mining sector in general. Anyway, mining and metallurgical activity in Greece is nothing new.

Therefore, let us forget the present and try to visualize the conditions that existed at least 2500 years ago. Exploitation of mineral wealth started well deep into the old ages.

If we consider the archaic period between 2500 BC and 1125 BC we must admit that our findings and information are very poor. By the end of the period it was known that gold existed mainly in Northern Greece (Macedonia, Thrace, Island of Thassos) in native state as well as in placer deposits. Some gold objects were found in central Peloponnese not far from a small placer deposit. Nevertheless the precise sources of the Minoan and the Mycenaean gold are not known. Probably some local sources had been used but soon they were exhausted. During the period 1125 BC to 800 BC metallotechnical activity considerably expands but the sources of metals still remain vague. It is interesting to note that gold is in fact a very commonly mentioned metal in the Iliad and Odyssey.

With the beginning of the 8th century BC several mining centers appear and develop (Rodopi, Paggaion, Thassos, Lavrion, Kythnos, Serifos, Sifnos etc.) and some of them became famous later. In Cyprus, copper and silver is also produced.

There is no doubt that among the famous mining and metallurgical centers of the Greek antiquity Lavrion remains at the top, not only due to the importance and duration of its activity but also for the value and significance of the spectacular archeological findings. Further to these, many ancient authors, poets, historians and geographers mention Lavrion in their works. That is why we are going to focus and mainly concentrate our lecture to the mining and metallurgical activity in the Lavrion area during ancient times. Before going into details on the subject we must say that the main metals known to the Greeks, with the exception of Gold, were rarely found in a free, e.g. native, state, but as compounds (ores).

Early, miners exploited placers and veins which outcroped on surface, but as these sources became exhausted the Greeks turned to underground mining. Generally speaking mining involved prospecting for and collecting the mineral, followed by a certain processing usually with the aim to enrich the precious material. The subsequent refining was covered by the metallurgical process. Plato, Aristotle, Theophrastus, Diodoros Siculus, Strabo, Hirodotus, Ploutarchos, Xenofon, Pliny are among the primary sources. These authors mainly recorded the location of minerals and processing techniques in their own times, but occasionally included fragments from earlier authorities.

Unfortunately their chronological evidence is often vague and confusing and different techniques are conflated by them in their descriptions.
The first attempts to exploit mineral deposits were limited to easily won ores (outcrops) which could readily be collected and treated in primitive furnaces. When vein mining began however, in each succeeding period, with the development of improved techniques, miners penetrated progressively deeper underground.
As all mining engineers know, it is in the nature of mining, that each phase of exploitation tends to destroy the evidence of earlier work, so that ancient mines are fundamentally poor subjects for archeological stratification.
An attempt to establish a precise chronological sequence is at best a comlicated matter and often virtually impossible. Nevertheless, in spite of this difficulty, they can provide a wealth of enlightening material concerning the various employed techniques.
As we will see, in our case of Lavrion, pits, opencast workings, adits, shafts, galleries, washers, furnaces, cisterns etc. are still intact and may be examined. Likewise, some tools and mine working devices, even in a fragmentary condition, can be found, contributing to the overall picture.
Piles of rejected material can yield valuable information not only about the scale of operations but, following analysis of their contents, evidence of the degree of the success and recovery achieved in processing and refining.
Coins, statues and other metal objects can give us important information, on the metallurgical side, when subjected to analysis by chemical, X-ray fluorescence, electron probe microanalysis, spectrometry or other techniques according to the case.
The composition of metal and alloys and their physical characteristics in turn reveal their method of manufacture and the mechanical work to which they have been subjected.
Now, let us go back to our Lavrion case. Lavrion lies at the Southern edge of Attica peninsula, at a distance of about 75 Km South-East of Athens. When really mining and metallurgical activity started in this area during the ancient times is not clear. It probably started during the middle of the 8th century BC, since there are indications that a certain production of Silver took place during the 7th century BC. In the 6th century BC the production of Silver was gradually increased and reached its peak during the 5th century BC when the glorious Classical period of ancient Greece started and Athens was under the leadership of an amazing statesman, Pericles, who created the well known Golden age.
At this point we must make a significant remark: During the year 483 BC a new rich deposit was discovered —the Maronia deposit— the exploitation of which tremendously pushed forward the activity which has, ever since, taken the form of an industry. The production of Silver was considerable during the next 4th century BC, but started to decline in the 3rd century. There was a revival towards the middle of the 2nd century but that was all. The time of the Roman domination was close enough. Indeed, during the first part of the 1st century BC (probably 87 BC) mining and metallurgical activity, which resulted to a total production of about 3500 tons of Silver, came practically to an end. Ever since Lavrion was forgotten, past into oblivion for almost 2000 years. It was covered by pine trees.

Geology

In order to cover the subject in a spherical way let us first give some general information concerning the geological and mineralogical picture of the Lavrion area.
There are five main geological strata composed of alternate layers of calciferous rocks (limestones and marbles) and of micaschists. These layers having different degrees of porosity offered different resistances to the upward thrust of hot, mineral rich liquids from the earth's depths.
In a typical cross section we notice —from up downwards— the upper schist (Cretaceous), the upper marble and the lower schist (Jurasic) and the lower marble (Precambrian). In this way three contacts are formed where the ore exists. The first and third contacts proved to be the richest ore bearing levels.

As already understood, the metalogenesis is of hydrothermal nature. Hot liquids with the dissolved metals came from deeper levels together with some granitic intrusions. Where granitic small veins appear the ore is somewhere about.
Ancient miners although had a very limited knowledge of geology knew very well this rule. They were looking for guides, e.g. the granitic veinlets, and they were following the contact in order to meet the mineral and when this disappeared they still followed the contact.

The ores are mixed sulfides, called BPG (from Blende, Pyrite, Galene) as well as oxidized minerals mainly smithsonite ($ZnCO_3$) and cerussite ($PbCO_3$).
The miners were only interested to find galena and cerussite because these minerals were argentiferous. Rich galena of the third contact could contain 1,2 to 1,4 Kg of Silver per ton of ore.

They naturally exploited the first contact and when the mineral was gradually exhausted, they were obliged to dig deeper, to meet the 2nd and 3rd contacts. Their effort to reach and exploit the rich third contact is obvious, but the shafts never exceeded the depth of 120 meters and no exploitation took place whenever there was water, e.g. below sea level. Speaking of water we must say that water was a great «enemy» of the ancient miner, since he had no means to pump it out of the mine and therefore he was forced to discontinue the exploitation. Otherwise they were obliged to employ large numbers of workers to get rid of the water, using special buckets. One of the earliest mechanical devices used in the ancient world was the Archimedean screw, known also as Egyptian screw, because Archimedes invented it when he was in Egypt. Diodorus Siculus describes it as «an exceptionally ingenious machine, by which an enormous amount of water is thrown out, to one's astonishment, by using an unsignificant amount of labour».

There is no doubt that this famous invention could consist a great patent of its time.

Mining

The earliest approach was to cut horizontally from the surface at the contact level, forming in such a way open cast pits and workings of considerable volume. Penetrating deeper they started driving gallieries, of very small cross section usually 0.6 m^2 (0.70m × 0.85m).

Only young boys could walk along them.

When the galleries met the metaliferous area were enlarged, in order to win the ore, forming considerable chambers or rooms. Where these rooms were quite large a column or pillar of natural rock or ore was left to support the roof. Obviously they applied the «room and pillar» mining method so widely used today in coal and metal mining.

Sometimes they tried to recover the rich mineral pillar by replacing it with a pile consisted of waste rock.

In thicher veins they were applying the Breast stoping technique.

As the length of the galleries increased ventilation problems inevitably appeared, forcing them to sink vertical shafts. Later, the shafts were sunk not only for ventilation purposes, since they served for exploration (reaching the contact) development and trasportation (hoisting) of the extracted meterial.

The ore was loaded into baskets and carried by workers (on their shoulders) who were climbing the ladders installed in the shaft.

Now, let us examine an interesting detail. Among the ancient shafts of Lavrion (more than 1000) you can notice that some are twins, e.g. sunk very close to one another (a few meters apart).

As it is obvious, there was no ladder installation in these shafts. Besides this, there was no connection between the shafts at the bottom level in order to create a certain ventilation current. Therefore, we come to the conclusion that, hoisting was performed with the aid of a pulley and counterweight. This is a fair explanation. If it is correct, it proves that pulleys were used in Lavrion by the end of the 4th century B.C. of course, another patent.

Some other forms of shafts were also used, mainly combination of inclined and vertical shafts, probably to facilitate hoisting and provide a sort of rest area for the workers.

The rate of advance of the galleries and the shafts was of course very low, probably a few centimeters per day. The miners used a limited range of hand tools: hammer with iron head, chisel or needles of iron for use with hammer, and shovels, mostly wooden.

To carry the ore would also use leather sacks or baskets of woven grass.

For lighting they had torches and oil-lamps specially disigned to last a whole work shift. Concerning topography, elementary mine maps were depicted on clay plates and stones.

Processing of the Ore

After a preliminary sorting of the lumps of ore underground, a secondary sorting was done outside near the shaft head or the gallery mouth to remove rock, sterile pieces. If the mineral collected in such a way was rich enough went directly to smelting.

As the exploitation became more intensive, especially during the 5th century BC, they were obliged to extract ore having a lower silver content, which needed a certain processing.

The first stage was to break the large lumps of ore into smaller pieces by hammering it with iron mallets of fairly flat - topped boulders or blocks of limestone or marble.

The second stage was to grind the already broken ore pieces into a fine, sandy, granulated form. This was done in hard stone mills of various kinds.

The flat type (hopper quern) mills were mostly used, consisted of trachyte. They measured 40 cm × 60 cm and were 15m high.

Some conical mills were also found but they were probably used only for grinding wheat. Nevertheless, this type of mill was «invented» again 2500 years later in the U.S. by Simon, the well known Simon's cone. In the meantime was widely used to grind corn in Pompeii up to 79 AD.

The next stage of ore processing was to wash the fine-milled ore in a flow of water, in order to separate the heavier grains of ore from the lighter grains of sterile rock. In this way a classification by gravity occurs and the ore is cleaned and concentrated, ready for smelting.

For this purpose two main types of washers were used: The level, rectangular which was the most common and the helicoidal (spiral) which was developed later, probably by the end of the 4th century BC.

There are many rectangular washeries scattered around the Lavrion area, but only a few have been uncovered, cleaned and maintained.

The method of operation was as follows: Water was allowed to flow through the funnel holes out of the main water tank and into wooden troughs (sluices) set in front of the tank on the washery's floor which was slightly inclined.

The trough's bottom contained cup-like depressions (traps) where the heavier grains of the ore (which finely ground was shoveled in the upper end of the trough) was concentrated. The water, still containing some ore and —of course— the lighter sterile grains continuing its flow went first into a transverse channel and then to consecutive channels and sedimentation basins. Finally the water would be freed from all ore and sterile rocks and so clarified would refill the water tank again.

The contents of the troughs were emptied and allowed to dry, whereas the contents of the channels and basins were also emptied and disposed, forming various piles.

Repetition of the process might be necessary to obtain maximum recovery of the argentiferous ore. There was a big problem with the water supply, since the Lavrion region is one of the dryiest in the country. That is why the sparse seasonal rainwater had to be collected and conserved in large round or rectangular cisterns to be used all the year round. In the helicoidal washeries water and ground ore was introduced at one end and due to the form and inclination of the helix the water carried the material from trap to trap depositing first rich ore, then poorer ore and finally sterile rock, reaching a lower tank in a clarified state, to be used again. The trough was cut into the upper surface of a series of large stone blocks, set side by side.

It was an ingenious, amazing achievement. Its principle was «invented» again 2300 years later by Humphrey with his well known «spiral concentraton». It is worth saying a few words concerning another remarkable achievement: the various mortars used for the lining of surfaces coming in contact with water, to make them impermeable, so avoiding leakages. As it was proven these mortars contained considerable amounts of PbO, Fe_2O_3, ZnO and MnO and were applied in three consecutive layers. Even to day they are ramarkably well preserved and present a complete impermeability.

Smelting, Cupellation and resmelting of the litharge.

The enriched, concentrated ore was next taken to the furnaces for smelting in order to recover the argentiferous lead in a metallic state. The ore was subjected to smelting under reducing conditions in vertical furnaces, using charcoal as a reducing agent.

The furnace had an inside diameter of about 1 m and its height probably did not exceed 4 m. Its structure consisted of micaschist and the internal walls were lined with fire clay.

The operation was continuous. The furnace was fed from the top with a mixture of ore (mainly oxidized ores and eventually small amounts —not exceeding 15%— of galena) and charcoal.

The necessary air was pumped in with the aid of hand blowers and the temperature was risen to 1000 - 1200° C.

The produced metal as well as the slag were emerging from a taphole near the floor.

Since the very finely ground —almost dusty— ore could not pass through the furnace they were obliged to follow a certain briquetting procedure, using various suitable claps as cementing agent. Where exactly this was done is not clear. Possibly it was done on the washeries floors and the briquettes were left there for some time in order to dry.

Furnaces might be placed progressively at some distance from the other mine works because they produced noxious fumes.

There were several ancient smelting sites located both on the coast and inland but the wholescale removal of the existing slags for re-smelting, since 1865, destroyed almost all traces, with the exception of three furnace sites that have been recently found and excavated. Ancient slags amounted to about 1.5 mo tons, containing 10% lead.

The molten metal produced in these furnaces was a mixture of lead and silver. In order to separate these two metals they were using cupellation furnaces. Air was pumped in vigorously, with the aid of blowers, and in the heat produced (by burning wood) the lead was oxidized to lead-oxide (PbO) or litharge, leaving the silver in a molten state of its own. The process required special cupels consisted of suitable refractory materials.

Cupellation was done at a temperature of 900-930° C and when the silver appears temperature must be increased to at least 960° C.

The whole process was very delicate. The quantities of the metal to undergo cupellation were very large and the silver content relatively low. Besides these, it was absolutely necessary to attain excellent recovery of silver, since litharge was later resmelted to produce metallic Lead and therefore any amount of silver contained in it was a definite loss.

The number of techniques used by the ancient metallurgists as well as their relative inventions are really astonishing. Just for example we mention the ancient Greek method of cupellation by dipping iron rods into the bath of the cupel, thus removing the litharge produced in consecutive layers sticked on the cold iron rods. Can anyone of us deny that this could become a great patent of its time.

Further heating of the litharge in a furnace similar to one used for smelting the ore could reduce —with the aid of charcoal— the lead oxide and produce lead metal again for commercial use. The lead contained small amounts of silver as well as several impurities, like Copper, Antimony and Arsenic etc. Refining was not needed at that time. Nevertheless, ancient Greek metallurgists invented and used a method of refinement of the lead by dipping tree branches the moisture of which oxidizes the more readily oxidized metals (Sb, As) forming a «froth» on the surface of the bath which is easily removed.

The subject of Mining and Metallurgical activity in the Greek ancient world is practically inexhaustible. During the last 20 years a lot of work has been done in the field and of course we must pay a tribute to the late Prof. C. Conophagos for his extensive research work, his findings and conclusions concerning ancient Lavrion.

As already mentioned, production in Lavrion started again —for the third time— since 1865, using the old slags and the poor mineral rejected during the ancient times. More intensive exploration work was performed and underground exploitation continued mainly at the third contact. A few years ago mining and metallurgical activity ceased again, after covering almost one century. Is there any chance to restart? This remains to be seen. If it so happens will be for the fourth time.

Mining rights - Labour force

The mines of ancient Lavrion belonged to the State. Any free man could obtain a concession, by paying the corresponding amount of money, and lease a certain mine, or even a certain gallery, for 3, 7 or 10 years, depending on the conditions that prevailed in the works. It seems that there were many operators as it is indicated by plates found on site. These operators could also be owners of washeries and smelting furnaces.

According to relative estimation there were 11.000 workers employed during the 5th century BC in the major Lavrion area, to produce 20 tons of Silver per year. Some of the workers, mainly of the supervising group lived around the mines in rooms having baths and showers and other facilities.

There were also slaves working in the various activities but it seems that their standard of living was tolerable. If they had an ingenious mind could be promoted to higher positions.

Influence of mining and metallurgical activities on ancient Greek culture and civilization.

The silver product of the Lavrion mines was taken to Athens to be minted into coins by the state and also exported elsewhere. The lead —1.400.000 tons were produced— was also used for domestic and commercial purposes. Copper was also a valuable product of the district, whereas iron was used for making necessary tools.

In archaic and classical Greece operations related to mining and metallurgy undoubtly played an important role in the creation of ancient civilization and at the same time offered the means to succesfully confront its various enemies. It is well known that a sudden peak in the production of Silver in Lavrion helped Themistocles to built a war fleet and win the sea battle of Salamis —in the year 480 BC— eventually creating an athenian Empire.

It must also be noted that by the middle of the 4th century BC, Philip, King of Macedonia, started an intensive exploitation of the Gold and Silver deposits in Paggaion mountain creating his own empire and giving to his son, Alexander the Great, the opportunity to venture his famous expeditions between 334 and 323 BC.

The influence of all these activities in the development of Classical Greece, the creation of the Golden age of Pericles, the temples and mosaics of Pella in Macedonia and the erection of glorious monuments like the Athenian Acropolis is overwhelming.

Apart from its other claims to fame, the importance assigned by Classical Greece to individual achievement assures it a place among the Great ages of man.

All these people working in Lavrion mines during the ancient times had almost nothing. They had no doctors to cure them, they had no drugs to fight their illnesses, they had no power to help them perform their work, they had no recreation besides a drama play in an open air theater. They had only their muscles and their amazing brains.

In the eternal darkness of the underground workings they had a faint, weak light to help them extract the valuable mineral, but —no doubt— in this light a tremendous power was hidden. The power and will of mankind to walk towards its destiny, through a steady, magnificent, inspiring progress. The light of progress.

ΠΕΡΙΛΗΨΗ

Η ΜΕΤΑΛΛΕΥΤΙΚΗ ΔΡΑΣΤΗΡΙΟΤΗΤΑ ΣΤΗ ΣΥΓΧΡΟΝΗ ΚΑΙ ΤΗΝ ΑΡΧΑΙΑ ΕΛΛΑΔΑ

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Η Ελλάδα, παρά τη σχετικώς μικρή έκτασή της (132.000 km^2), εξεταζόμενη μεταλλευτικώς, παρουσιάζει πληθώρα εμφανίσεων διαφόρων χρησίμων ορυκτών, μερικά από τα οποία έχουν σημαντική βιομηχανική σπουδαιότητα.

Όπως προκύπτει από πολυάριθμες σχετικές μελέτες αποτέλεσμα της επισυμβάσης στον Ελληνικό χώρο μεταλλογενετικής δράσεως, υπήρξε ο σχηματισμός μεγάλου αριθμού αξιόλογων κοιτασμάτων, η δε εν γένει γεωλογική δομή της Ελλάδας παρουσιάζει ευνοϊκές συνθήκες μεταλλοφορίας. Ενδεικτικά αναφέρονται τα κυριώτερα ορυκτά του Ελληνικού χώρου: Λιγνίτης, τύρφη, βωξίτης, μαγνησίτης, σιδηρονικελιούχα μεταλλεύματα, χρωμίτης, σιδηροπυρίτης, μεικτά θειούχα μεταλλεύματα Pb, Zn, Fe, περλίτης, μπεντονίτης, χαλαζίας, άστριοι, βαρυτίνη, γύψος, κίσσηρη, αμίαντος, μάρμαρα.

Αξιοσημείωτο είναι ότι η Ελλάδα κατέχει το 2,75% των παγκοσμίων αποθεμάτων βωξίτη και είναι η μόνη χώρα της ΕΟΚ που παράγει βωξίτη, σιδηρονικέλιο και σιδηροχρώμιο, ενώ παράλληλα είναι η πρώτη χώρα στην Ευρώπη και η δεύτερη στον κόσμο σε παραγωγή περλίτη και μπεντονίτη, καλύπτει δε και ποσοστό 8,5% περίπου της παγκόσμιας παραγωγής μαγνησίτη.

Η Ελληνική μεταλλευτική βιομηχανία αναπτύχθηκε με ταχύ ρυθμό μετά το δεύτερο παγκόσμιο πόλεμο και έκτοτε έπαιξε σημαντικό ρόλο στη βιομηχανική ανάπτυξη της χώρας.

Εν τούτοις, κατά τα τελευταία χρόνια αντιμετωπίζει πολλά και σοβαρά προβλήματα, οφειλόμενα κυρίως στη με χαμηλό κόστος υπερπαραγωγή ορισμένων πλουσίων μεταλλευτικώς χωρών (Νότιος Αφρική, Αυστραλία), στον ανταγωνισμό από τις χώρες των συμφωνιών Lome (που επιπροσθέτως βοηθούνται από την ΕΟΚ μέσω του χρηματοδοτικού ταμείου SYSMIN) και στις δραματικές εξελίξεις που σημειώθηκαν στις χώρες της Ανατολικής Ευρώπης, με αποτέλεσμα τη διακοπή ή τη δραστική μείωση των εξαγωγών Ελληνικών μεταλλευτικών προϊόντων προς ορισμένες από τις χώρες αυτές. Επιπροσθέτως, η απροθυμία της ΕΟΚ να θεσπίσει μία αποτελεσματική Κοινοτική μεταλλευτική πολιτική επιτείνει την υφισταμένη δυσχερή κατάσταση, η αντιμετώπιση της οποίας απαιτεί, μεταξύ άλλων, σύντονες προσπάθειες, εκ μέρους όλων των αρμοδίων φορέων, οργάνωση και εκσυγχρονισμό της Ελληνικής μεταλλευτικής βιομηχανίας. Οπωσδήποτε όμως, η άσκηση της μεταλλείας στον Ελλαδικό χώρο δεν αποτελεί δραστηριότητα πρόσφατη. Είχε αρχίσει από τους αρχαίους χρόνους, σποραδικά ίσως από τη Μυκηναϊκή εποχή. Αργότερα, από τον 8ο π.Χ. αιώνα ορισμένα μεταλλευτικά κέντρα (Ροδόπη, Παγγαίο, Θάσος, Λαύριο, Κύθνος, Σέριφος, Σίφνος, Κύπρος κ.ά.) παίρνουν περισσότερο συγκεκριμένη μορφή, ενώ η εκμετάλλευση του ορυκτού πλούτου –ιδίως του αργύρου και του χρυσού– κορυφώνεται κατά τους Κλασσικούς χρόνους (από τον 5ο π.Χ. αιώνα) κυρίως στο Λαύριο και τη Μακεδονία. Χωρίς αμφιβολία το Λαύριο απετέλεσε το πιο σημαντικό μεταλλευτικό και μεταλλουργικό κέντρο της αρχαίας Ελλάδας και η συμβολή του ήταν καθοριστική σε κρίσιμες περιόδους της Ελληνικής ιστορίας.

Ο ερευνητής της αρχαίας μεταλλευτικής και μεταλλουργικής δραστηριότητας στο Λαύριο μένει έκπληκτος μπροστά στο πλήθος των μεγαλοφυών επινοήσεων των αρχαίων Ελλήνων, οι οποίοι εδημιούργησαν μίαν ανεπανάληπτη τεχνική προκειμένου να εξορύξουν και εμπλουτίσουν το αργυρούχο μετάλλευμα και στη συνέχεια, με κατάλληλη σειρά μεταλλουργικών διεργασιών, να επιτύχουν την απόληψη καθαρού αργύρου και μολύβδου.

Οι τεχνικές που χρησιμολοιήθηκαν τότε είναι οι ίδιες με αυτές που χρησιμοποιούνται και σήμερα. Μόνο ο εξοπλισμός έχει αλλάξει. Γι' αυτό άλλωστε πολλές από τις θαυμαστές επινοήσεις των αρχαίων «εφευρίσκονται» και πάλι σήμερα –μετά από 2500 περίπου χρόνια– υπό την αυτή σχεδόν μορφή.

3.500 τόννοι αργύρου και 1.400.000 τόννοι μολύβδου παρήχθησαν στο Λαύριο από τον 7ο αιώνα μέχρι τον 1ο αιώνα π.Χ., πλούτος ο οποίος συνέβαλε αποφασιστικά στη δημιουργία του θαυμαστού αρχαίου Ελληνικού πολιτισμού και στην αντιμετώπιση των εχθρών του Ελληνικού έθνους.

Χωρίς αμφιβολία, οι πρόσφατες ερευνητικές προσπάθειες του αείμνηστου Καθ. Κ. Κονοφάγου και των συνεργατών του πρέπει να συνεχισθούν και ολοκληρωθούν, ώστε το Λαύριο να αποτελέσει ένα παγκοσμίου ακτινοβολίας μεταλλευτικό και μεταλλουργικό μνημείο, οι επισκέπτες του οποίου θα έχουν την δυνατότητα να θαυμάζουν τα επιτεύγματα των αρχαίων Ελλήνων και τις περίφημες επινοήσεις του ανθρωπίνου πνεύματος.

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